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| | | |
|---|---|---|
| 1. | Your reference | CMYK/NIR/CAM |
| 2. | Patent application number *(The Patent Office will fill in this part)* 10 MAY 2002 | 0210626.8 |
| 3. | Full name, address and postcode of the or of each applicant *(underline all surnames)* | TITECH AUTOSORT AS<br>RYENSVINGEN 11<br>N-0680 OSLO<br>NORWAY<br>10MAY02 E717343-1 D02691<br>P01/7700 0.00-0210626.8 |
| | Patents ADP number *(if you know it)* | 08305146001 |
| | If the applicant is a corporate body, give the country/state of its incorporation | |
| 4. | Title of the invention | METHOD AND APPARATUS |
| 5. | Name of your agent *(if you have one)*<br>"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | ANTHONY BURROWS<br>BUSINESS CENTRE WEST<br>AVENUE ONE, BUSINESS PARK<br>LETCHWORTH GARDEN CITY<br>HERTFORDSHIRE<br>SG6 2HB |
| | Patents ADP number *(if you know it)* | 00031666001 |

| | | Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|---|---|
| 6. | If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number | United Kingdom | 0200922.3 | 16/01/02 |

| | | Number of earlier application | Date of filing *(day / month / year)* |
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| 7. | If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application | | |

| | | |
|---|---|---|
| 8. | Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*<br>*a) any applicant named in part 3 is not an inventor, or*<br>*b) there is an inventor who is not named as an applicant, or*<br>*c) any named applicant is a corporate body.*<br>*See note (d))* | YES |

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| Abstract | |
| Drawing(s) | 10 |

10. If you are also filing any of the following, state how many against each item.

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| Priority documents | |
| Translations of priority documents | |
| Statement of inventorship and right to grant of a patent *(Patents Form 7/77)* | E |
| Request for preliminary examination and search *(Patents Form 9/77)* | |
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| Any other documents *(please specify)* | |

11. I/We request the grant of a patent on the basis of this application.

Anthony Burrows

| Signature | Date |
|---|---|
| ANTHONY BURROWS - AGENT | 10 MAY 2002 |

12. Name and daytime telephone number of person to contact in the United Kingdom

CHRISTOPHER BROTHERS
01462 481755

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# METHOD AND APPARATUS

This invention relates to automatic sorting of cellulosic material for recycling of at least one class of the materials.

Waste cellusolic material includes white paper, coloured paper, cartons and corrugated cardboard. These may or may not be printed, for example CMYK or black-ink printed, such as for newsprint, illustrated magazines and books.

Today the sorting process is to a large degree carried out manually.

According to a first aspect of the present invention, there is provided a method comprising identifying CMYK-printed matter by irradiating the matter with radiation which is varied by the matter differently if the matter is CMYK-printed than if the matter is not CMYK-printed.

According to a second aspect of the present invention, there is provided apparatus for use in identifying CMYK-printed matter, comprising radiation-emitting means serving to emit radiation which is varied by the matter differently if the matter is CMYK-printed than if the matter is not CMYK-printed, and detecting means serving to detect the varied radiation.

Owing to these aspects of the invention, it is possible to identify CMYK-printed matter in an automatic manner.

According to a third aspect of the present invention, there is provided a method of separating, from a mixture of objects, CMYK-printed objects from objects which are not CMYK-printed, comprising advancing said mixture, determining,

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using radiation, whether a portion of said mixture is a CMYK-printed object, and separating from the mixture the CMYK-printed objects as desired portions of the mixture.

According to a fourth aspect of the present invention, there is provided apparatus comprising means for producing advancement of a mixture of CMYK-printed objects and objects which are not CMYK-printed, means which uses radiation to determine whether a portion of the mixture is a CMYK-printed object, and means for separating from the mixture the CMYK-printed objects as desired portions of the mixture.

Owing to these aspects of the invention, it is possible to sort out CMYK-printed objects from other objects in an automatic manner and so avoid manual sorting, which is not only costly but also unattractive work. In a preferred embodiment, a conveyor belt advancing a stream of waste cellulosic material is scanned over its entire width with a CMYK sensor. The type of print material and process can then be reliably identified. Printed grey and brown paperboard and cardboard are often printed in only three colours. A CMYK sensor can detect reliably the number of printing strata and also the composition of the colours. Thus, desired paper, such as magazines, can be clearly distinguished from printed paperboard and cardboard.

If it is additionally desired to determine whether or not an object is composed of polymer or of polymer-coated material, with or without a view to separating from a mixture the object in question, NIR (Near Infrared) spectral detection can be employed. In this way, it becomes possible to identify

polymer or polymer-coated objects which may be unwanted or may be a desired class of material.

The conveyor belt would thus also be scanned over its entire width with a NIR sensor. Such sensors are well known from polymer and plastics sorting. In this way, non-cellulosic material is identified; beverage cartons and plastics belong to this category. In particular, polymer coatings on cellulosic material can be identified. With the NIR sensor technique a number of material characteristics can be detected and distinguished.

If it is additionally desired to identify one or more, or even most or all, of the commonly occurring fractions in a stream of waste cellulosic material, in particular to identify and separate out the fractions, such as newsprint, magazines, white ledger paper and books, of interest for production of de-inkable pulp, a colour image-capturing device, such as a CCD (charge coupled device) can be employed in determining one or more, or even most or all, of the following image characteristics of the waste objects:

Multi-colour,
Homogeneity,
Text-and print-distribution,
Surface reflectivity,
Surface area,
Colour richness,
Corner straightness,
Edge relations,
Edge properties,

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by image processing of data signals from the device. Such camera image interpretation is described in DE-A-10059034.

Such a camera alone is seldom able to distinguish reliably coloured cartons from illustrated magazines as, to the camera, these look very alike. Similarly, to separate grey cellusolic material from brown cellusolic material has proven difficult, based on camera image interpretation alone.

Another of the main problems up to now has been to distinguish between grey and white paper without print.

With the more elaborate colour spectral analysis undertaken in the CMYK detection, it is possible to supplement the camera image interpretation, and overcome many of the above-mentioned problems. Likewise, NIR spectral data can assist in material identification; particularly in identifying unwanted material such as polymer and polymer-coated objects.

The following are a number of examples of how camera image interpretation can supplement the detection and sorting-out of CMYK-printed matter in waste sorting. The above-mentioned image characteristics are defined as follows:

"Multi-colour" means the degree to which colours such as red, green and blue are occurring and their relative shares of the surface area.

"Homogeneity" means the colour uniformity and brightness across the object.

"Text and print distribution" means determining patterns on the surface, such as the statistical distribution of black and white pixels, occurrence of column text, headings,

pictures and illustrations.

"Surface reflectivity" means the degree to which incident light is reflected from the surface of an object.

"Surface Area" means the plan size of the object.

"Colour richness" means the number of colours occurring and their surface relation to each other, and also the degree of difference (contrast) to each other. This requires arranging the pixels in different colour classes.

"Corner straightness" means the degree to which the shape of the object deviates from a circumscribed rectangle.

"Edge relations" means the length relation between the longer and the shorter edges of the circumscribed rectangle.

"Edge properties" means mainly the smoothness of the edges and is a measure of how uniformly and smoothly the edges extend.

Examples of how these characteristics can be interpreted for effective sorting of waste cellulosic material are as follows:

From the "Multi-colour" characteristic a decision can be made as to whether the identified object is a coloured paper or not. The lack of "Colour richness" together with a high degree of "Homogeneity" indicates that the object is cardboard, and in particular corrugated cardboard and cartons for packaging. A supplementary characteristic can also be the surface "reflectivity" which for almost all cardboard and cartons can be expected to be quite low. "Text and print distribution" comprises characteristics of text, illustrations etc. In particular headings, characteristics of

illustrations and of areas without print, can help in deciding whether the object is newsprint or not. "Multi-colour" will also give an indication as to whether the object is an illustrated magazine or not. "Corner straightness" may also confirm that it is a magazine or newsprint. Likewise "Edge relation" can lead to a further limitation in the possible classification choice in that, for instance, magazines normally would be in a standard format, e.g. the A4 format in Europe. Cartons and cardboard can normally be identified and distinguished from paper on the basis of the "Edge properties". Paper will normally have smooth edges, whereas torn cartons and cardboard will have jagged and frayed edges.

The colour in areas of the object without print may in many cases be characteristic of the paper type. This is often the case for paper for newsprint. Several types of carton and cardboards also have very characteristic base colours. Lightly coloured (tinted) paper usually has colours of a pastel type (pink, yellow) with a low degree of saturation.

Camera image interpretation, NIR detection and CMYK detection can be combined in a single system. In this connection it is unimportant in what sequence the sensors are scanning, if it is not done simultaneously. In one embodiment, all of the detectors (namely the NIR and CMYK sensors and the image-capturing device) scan the same transverse line across the conveyor belt.

All information from the various detectors is transmitted to a high-performance computer for processing.

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Algorithms are applied to identify the objects and define their respective categories and fractions.

According to a preferred embodiment, the sorting process normally is "negative" (i.e. removal of unwanted objects from the stream), and arranged in the following three steps.

1. The accurate position of the object is determined. This can be undertaken by the scanning CMYK or NIR sensors, or by means of the camera if used. Colour image interpretation, CMYK and NIR sensors yield the necessary object data.
2. The identified objects are characterised and arranged in the different waste fractions.
3. The identified undesired objects are finally ejected from the stream automatically by means of an array of controlled air jets arranged at the end of the conveyor belt.

The position detection of objects on the conveyor belt and the targeted air jet ejection is known from the sorting of plastics and polymers and described in DE-C-19751862, in which the object identification is undertaken without mechanical contact over the width of the conveyor belt, which can be 1400mm or 2800mm.

In order that the present invention may be clearly and completely disclosed, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 shows diagrammatically a system for identifying a CMYK-printed paper object, with a view to separating it from objects which are not CMYK-printed or are not paper

objects,

Figure 2 is a graph of normalised light intensity plotted against wavelength and showing visible light absorption spectra for the basic colours Cyan, Yellow and Magenta of the CMYK colour range,

Figures 3 and 4 are graphs showing respective examples of spectra of combined CMYK colours,

Figures 5 and 6 are graphs showing respective examples of spectra of non-CMYK colours,

Figures 7 and 8 are graphs showing spectra of brown cardboard and grey cardboard, respectively,

Figure 9 is a graph showing a spectral response in an example of the present method, and

Figure 10 shows diagrammatically a modified version of the system.

Referring to Figures 1 to 9, we propose a technique to discriminate between different classes of recycled paper, e.g. the de-inkable class and the unwanted material, based on the spectral properties in the visible region of the CMYK colours. CMYK is named after the colours Cyan, Magenta, Yellow and Carbon Black that result from the colour separation process used in most image rendering printing processes today. The colours obtained by the CMYK printing process can to a large extent be identified by properties in the visible spectrum distinguishing them from colours of tinted paper materials and paper objects printed by a premixing process. This colour distinguishing technique may employ a system such as disclosed in International Patent

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Application Publication WO96/06689; of course, visible light would be employed rather than IR. Moreover, this colour distinguishing technique may be combined with a technique using IR (infrared)-properties to remove paperboard objects (mainly food containers) printed by the CMYK process but having some form of plastics coating. The latter technique could be that disclosed in WO96/06689. A scanning system combining both techniques is shown in Figure 1. In the system shown, a mixture of various cellulosic sheets (S) are advanced continuously on a conveyor belt 1 past a detection station 2 having a scanner 3 which scans the stream of the advancing mixture transversely of the belt 1 and includes two analysis units 4 and 5. The radiation in the beam B reflected from the belt 1 and the sheets (S) has its visible light spectrum used by the unit 4 to identify CMYK-printed cellulosic sheets and has its IR spectrum used by the unit 5 to identify such sheets as plastics-coated cellulosic sheets. In this manner, it is possible to leave, as a main stream, only CMYK-printed paper sheets, black-and-white paper sheets and white paper sheets.

Newsprint and magazines are to a large extent CMYK printed, or printed in carbon black. Thus these may be distinguished from most other coloured paper objects by detecting the CMYK print. As mentioned CMYK may be distinguished from most other colours by the characteristics of the spectrum in the visible region. Figure 2 shows spectra for the three basic colours Cyan (dashed line), Yellow (solid line) and Magenta (dot-dash line). Figures 3 and 4

show examples of spectra of images printed by the CMYK colours, whereas Figures 5 and 6 show spectra of non-CMYK colours, Figure 7 shows a typical spectrum of brown cardboard, and Figure 8 shows a typical spectrum of grey cardboard.

As a measure of the "CMYK content" of a colour we detect the differences of the spectrum intensities among two or more of a multitude of narrow-frequency-band channels. The channels may be produced by light sensors fitted with narrow band transmission or reflection filters, or by placing sensors in selected positions along a spectrum generated by a dispersive element such as a grating or a prism. The number of channels is advantageously 5, 6 or more. Figure 9 shows the spectral response of a practical example with 5 channels, superposed on spectra of a typical CMYK colour spectrum (dashed line) and a non-CMYK spectrum (solid line) of a coloured paper.

One criterion for discriminating between CMYK and non-CMYK colour is differences among the levels of intensity in two or more of the channels, e.g. (Ich2 - Ich1), (Ich4 - Ich3) and (Ich5 - Ich4). Here, Ich*n* means the intensity measured in channel *n*. Other combinations of sums and differences of channel intensities may be chosen according to the type and number of paper qualities to be sorted.

The system shown in Figure 1, using NIR detection and CMYK detection, can be very advantageous. However, it has several limitations in covering the full range of waste cellulosic material sorting demands. The system shown in

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Figure 10 is better able to cover that full range, since it employs additionally a colour camera, particularly a CCD (charge coupled device) camera.

As shown in Figure 10, a conveyor belt 101 transports the waste cellulosic material beneath a CCD camera 102 contained in a casing 103, which also contains a CMYK sensor 104, a NIR sensor 105 and a computer 106 to which are fed the outputs from the items 102, 104 and 105. The sensors 104 and 105 receive radiation from lamps 107 as reflected from the waste stream, via a beam splitter 108. The computer 106 controls the operation of air valves for compressed air nozzles 109 so as to eject unwanted material, such as cardboard, colour-saturated objects and plastics from the stream, which continues as desired material of de-inkable quality.

The CMYK and NIR sensors 104 and 105 and the colour camera 102 scan the entire width of the conveyor belt 101. In this embodiment, the camera 102 is placed upstream of the other scanning sensors 104 and 105, and has a resolution sufficient to recognise printed text on the objects.

As the optical colour camera 102 a three-CCD, line camera (red, green and blue) is recommended. The resolution can here be 2000 pixels per line, and theoretically up to 8000 lines per second can be scanned, although the scanning speed is likely to be somewhat lower, because of the limited processing capacity of the image analysis computer 106.

This technology also allows, as an example, to distinguish between newsprint and grey carton, which normally

is very difficult to do. The basis is the statistical distribution of black and non-black pixels, whereby areas with given distributions may be classified as text areas.

The system according to Figure 10 can automatically sort waste into various fractions of high purity. As an example, an operator of the system has the opportunity of choosing only newsprint to be sorted out, or paperboard and cardboard, or any other desired fraction. It is also possible to set differing quality and purity standards.

The system of Figure 10 is capable of identifying the following cellulosic material fractions:

- <u>brown cellulosic material</u> (identification of specific colours, such as brown, light brown, dark brown, with the aid of the camera and/or the CMYK- and/or the NIR-sensors);
- <u>grey cellulosic material</u> (identification of specific colours, such as grey, light grey, dark grey with the aid of the camera and/or the CMYK- and/or the NIR-sensors. With a high-resolution camera, newsprint can be distinguished from grey cellulosic material);
- <u>newsprint</u> (the statistical distribution of black and white pixels enables the reliable detection of newsprint. This information is applied to differentiate unambiguously between grey paperboard or cardboard and newsprint. (If the operator so desires, a fraction consisting of newsprint only can be sorted out);
- <u>printed board</u> (this is cardboard with print which cannot be identified by a colour camera alone. A CMYK sensor

can give supplementary information, based on the fact that illustrated magazines always exhibit four printing colour strata, so that they can be distinguished from this printed board);

- coloured paper (these can be identified owing to their typical colours such as pink and yellow, and their distribution over the surface. This identification is best undertaken with a camera);
- non-paper (by applying a NIR sensor, all objects that are not composed of cellulose and that do not belong in the paper fractions can be identified. This category comprises mostly all polymers such as PVC, PP, PE, PET, PS, plastics foils, and beverage cartons and food packaging cartons with polymer coatings).

To ensure an optimum performance of the system with high "hitting rate" and low content of impurities in the sorted fraction, the input material needs to meet certain requirements. The input stream often arrives in heaps and bundles, in which case it should be run through ballistic separators, star screens, screen drums and/or similar machines to try to ensure that material is arriving in a single layer, and that impurities and fragments smaller than 80-100mm, metal impurities, and objects larger than 600mm, are removed mechanically beforehand. Ideally, the plan size of the object on the conveyor belt 101 should correspond to the size range of the de-inkable fraction. Further, the stream of objects should be well distributed across the conveyor belt surface in a single layer and with limited

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overlap of objects.. The system is operated with a belt speed of about 2.5 m/s preferably. A uniform input feed rate to the sorting station is of importance for an optimum system function with a high "hitting rate" and high purity of the sorted fraction. In addition, it is important that the belt 101 should operate without vibration disturbance.

If these requirements are met, a system throughput of some 3 to 4 tons per hour can be expected with a belt width of 1400mm. The material distribution should be near to the optimum, so that the ejection of grey and brown paperboard or cardboard can be at least 80%. The de-inkable material loss, referred to the input stream before sorting, could be expected to be about 4 to 5%.

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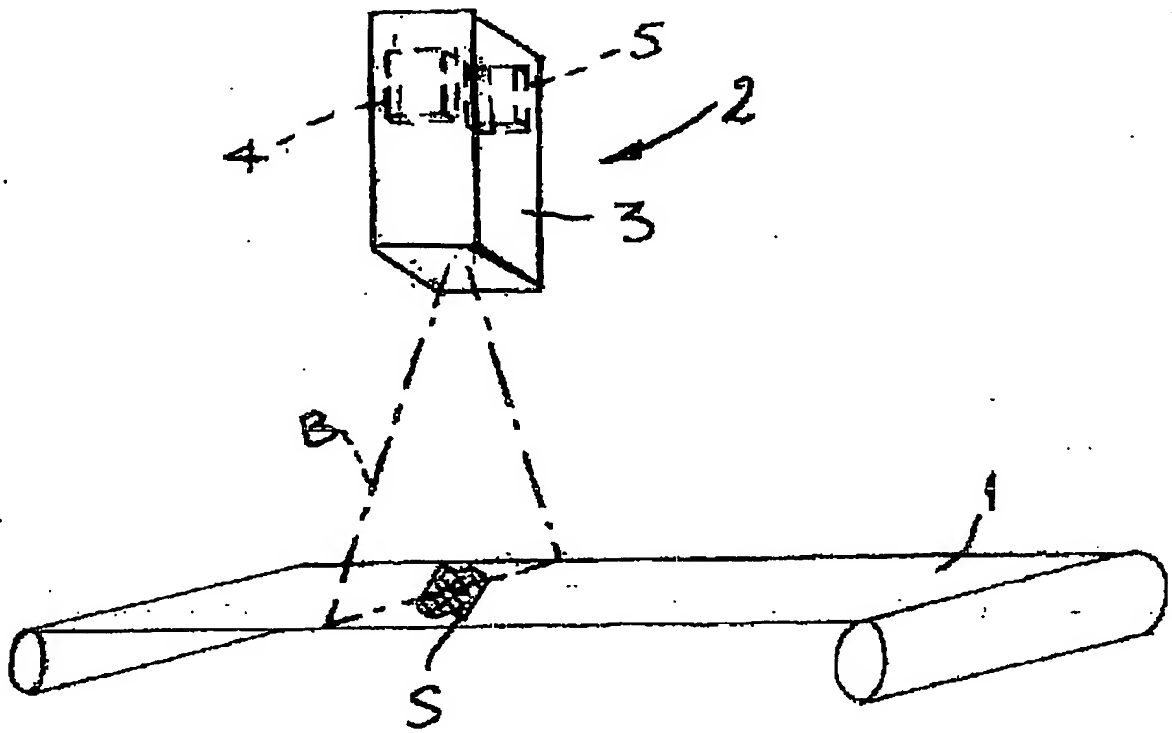


Fig. 1.

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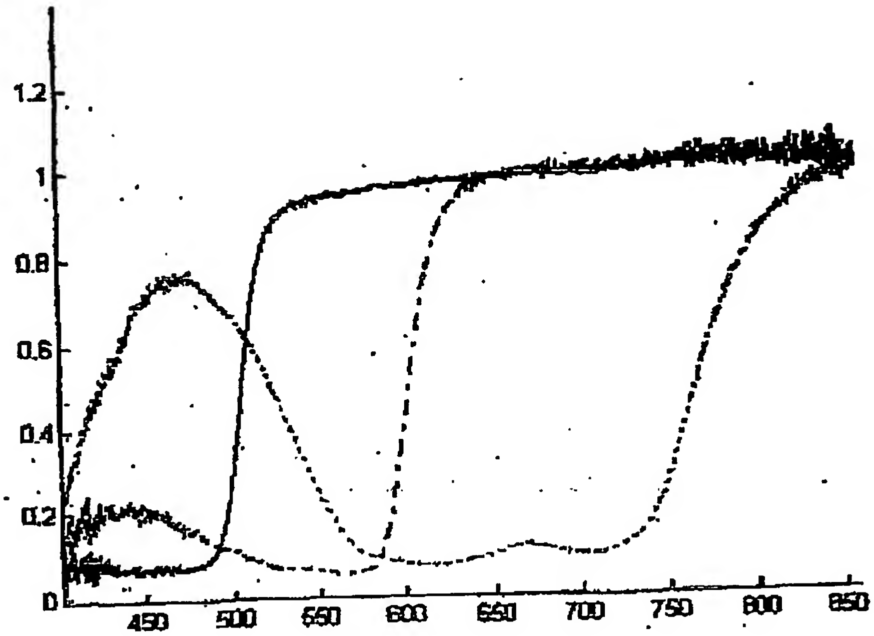


**Fig. 2.**

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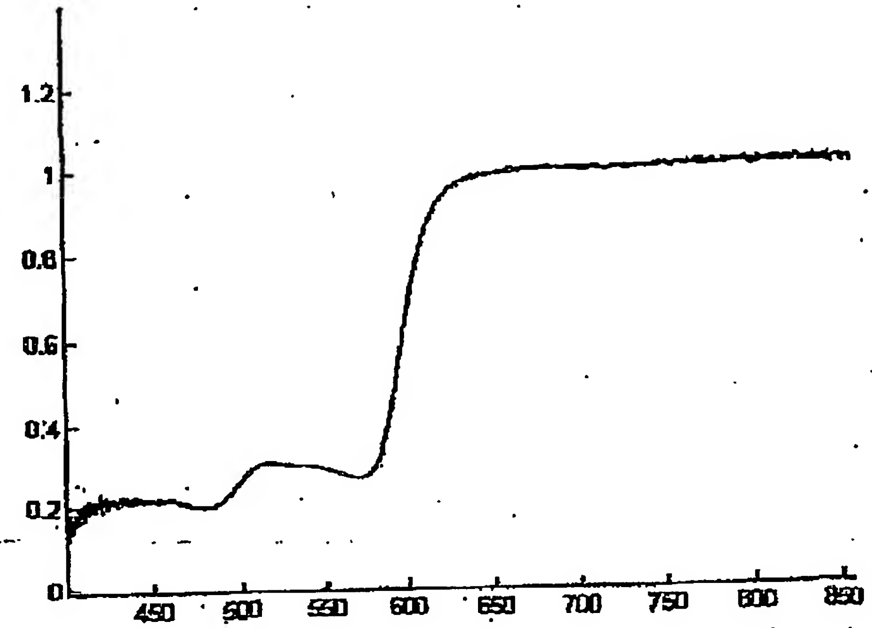


Fig. 3.

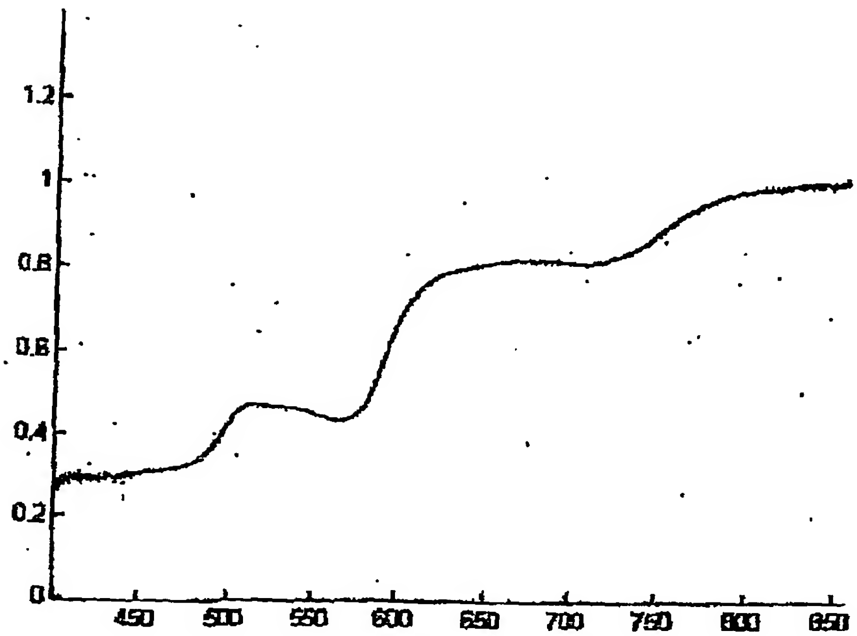


Fig. 4.

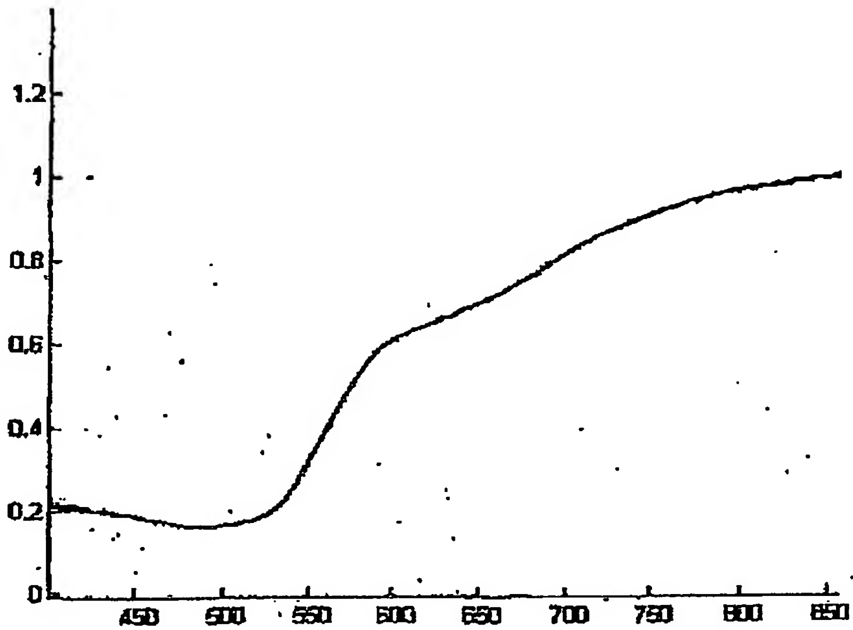


Fig. 5.

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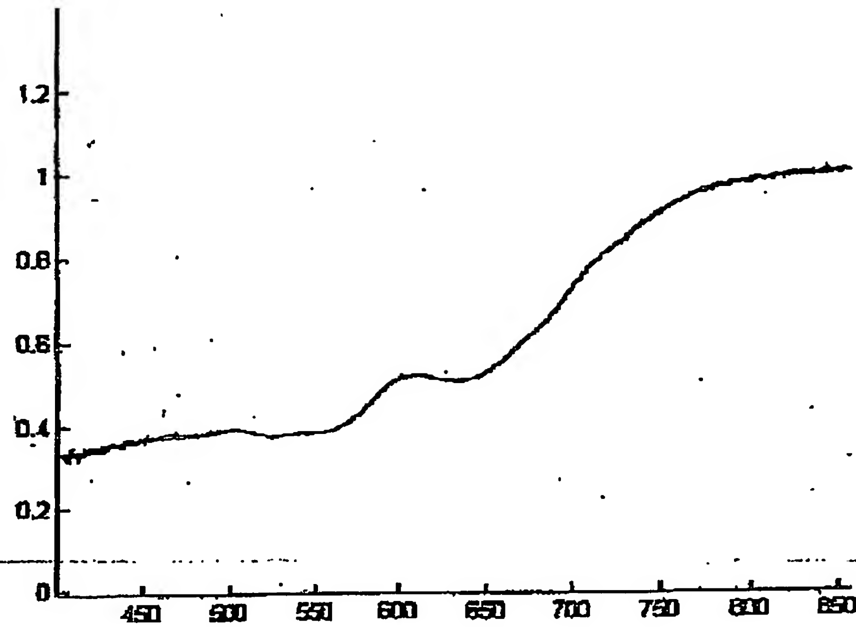


Fig. 6.

7/10

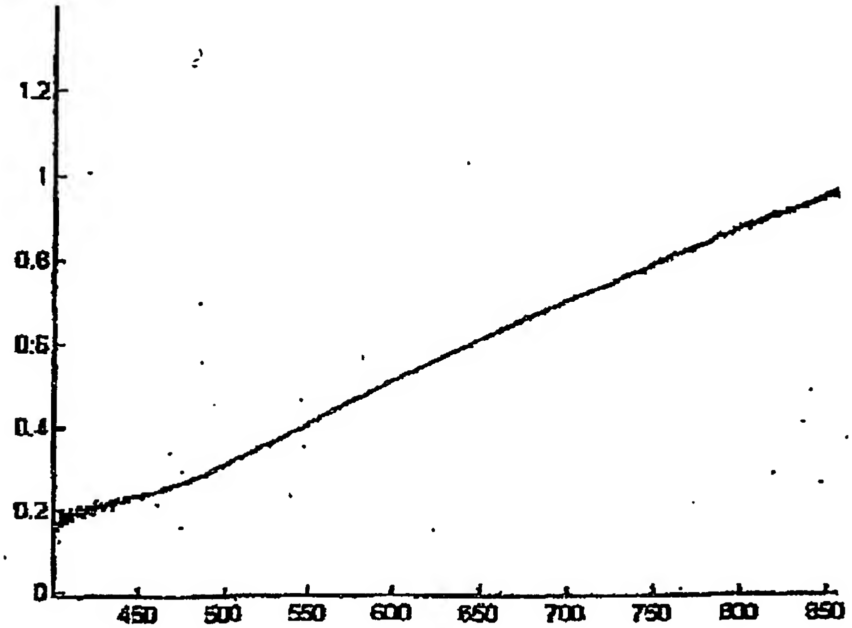


Fig. 7.

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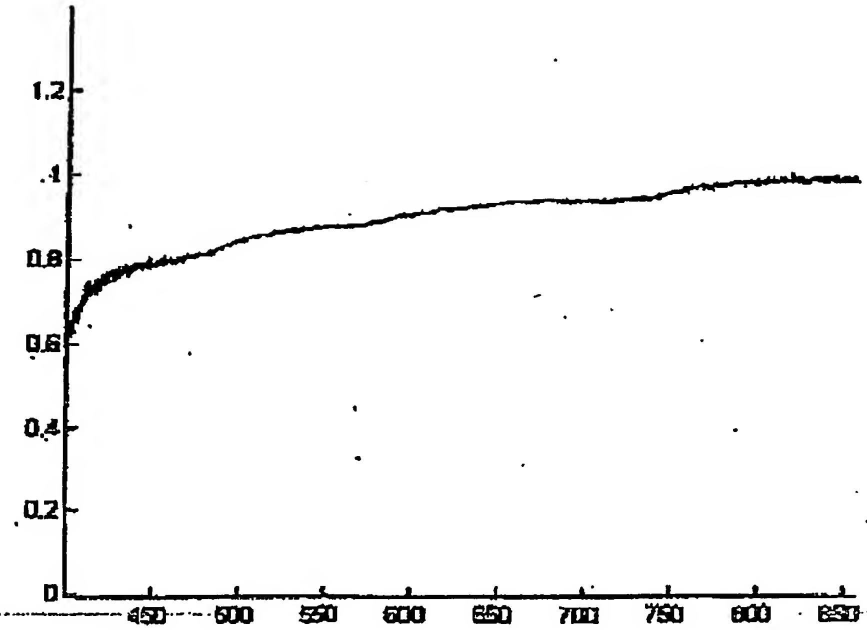


Fig. 8.

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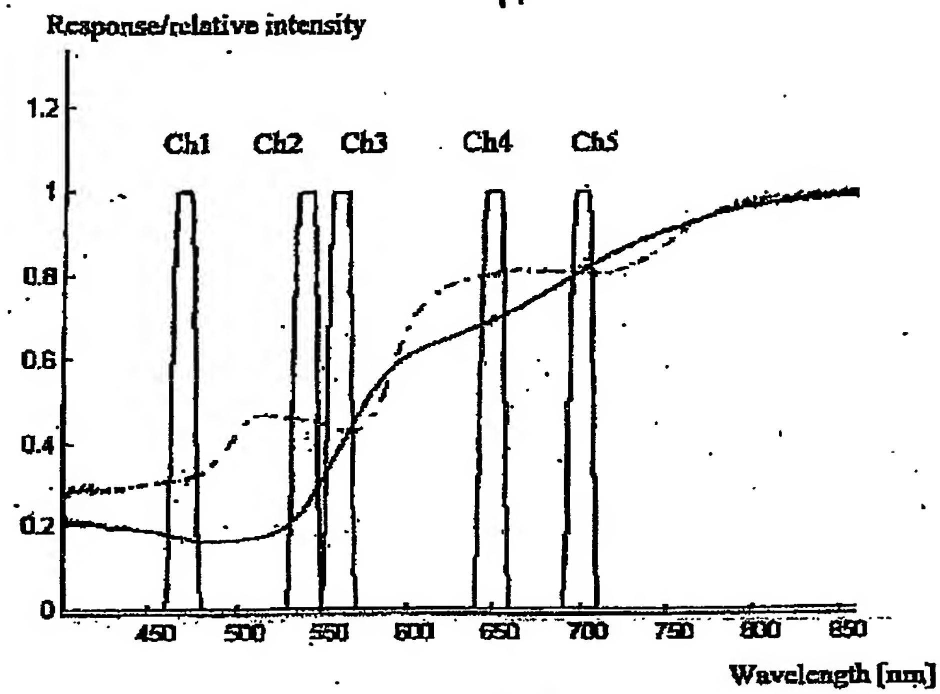
Response/relative intensity
1.2
1
0.8
0.6
0.4
0.2
0
Ch1
Ch2
Ch3
Ch4
Ch5
450
500
550
600
650
700
750
800
850
Wavelength [nm]

Fig. 9

# TiTECH Visionsort
## Block diagram Paper sorting

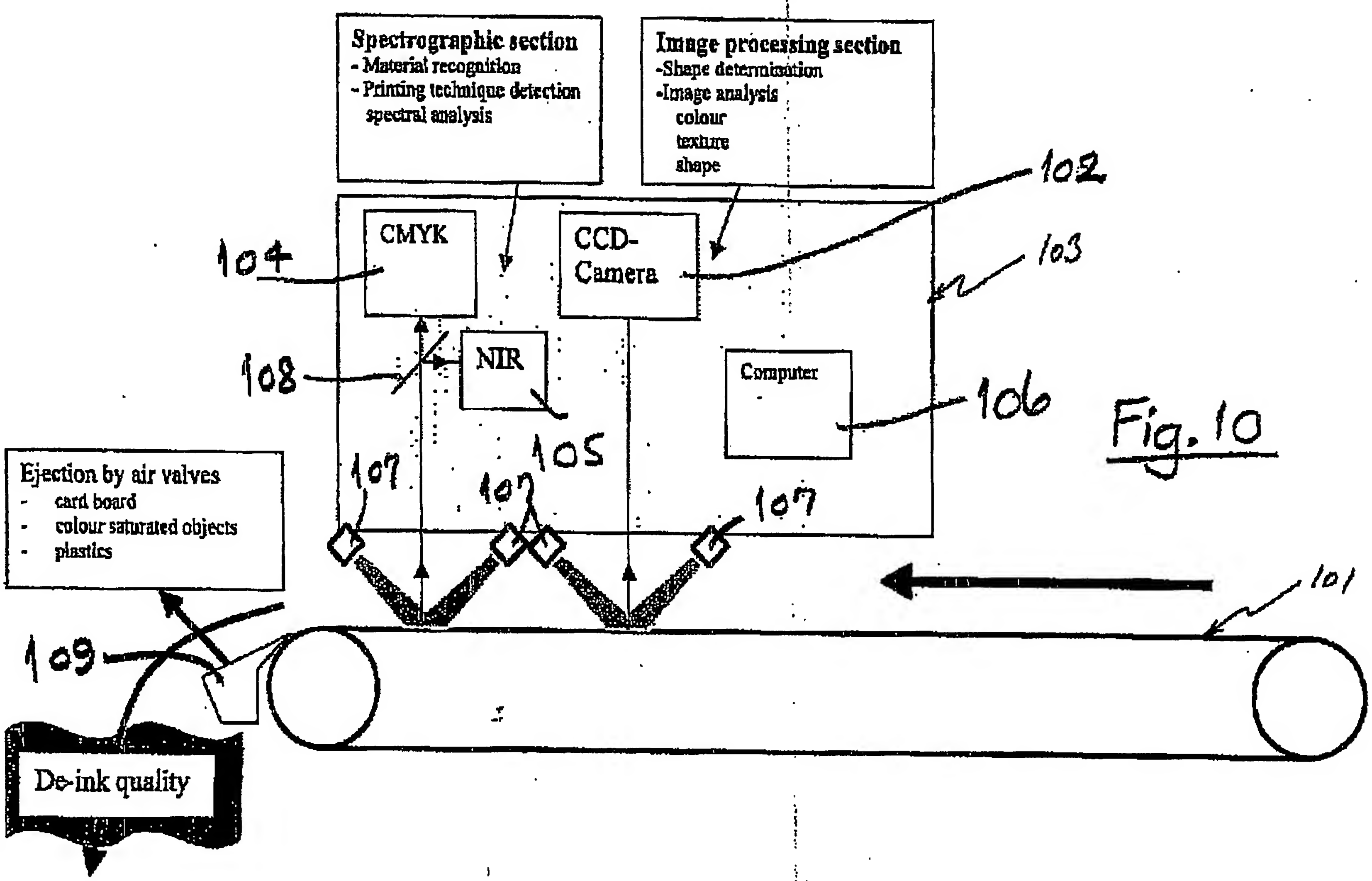


Fig. 10

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SB